2018 MAX-C/ExoMars Mission: The Orleans Mars-Analogue Rock Collection for Instrument Testing

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Introduction: The joint NASA/ESA Max-C/ExoMars two rover mission to Mars in 2018 will have a complementary instrument suite to investigate the texture and composition of the surface rocks, as well as the inorganic and organic composition of subsurface samples obtained by drilling. The science objectives of ExoMars are to search for traces of past or present life and to document the water/geochemical environment as a function of depth in the shallow subsurface. Max-C seeks to determine the habitability of the surface of Mars and caching rocks potentially containing traces of life for the future MSR mission. Testing the instruments on the two rovers with the same suite of Mars-analogue rocks will help in optimizing the science return of the mission. With this objective in mind, in Orléans at the OSUC analogue rock collection we have characterized a representative selection of Mars-analogue rocks using standard laboratory instrumentation [1]. Other samples will become ready as our lithotheque expands.

Materials : Our rock collection covers many of the lithologies found on Mars [2-4] and includes a variety of basalts (plus cumulates), volcanic sands deposited in shallow-water environments, a banded iron formation (BIF), and the clay nontronite. Some of the rocks have been subjected to hydrothermal alteration (silicification) and some of them contain fossil, carbonaceous traces of life.

Basalts: ***(1)*** An ultramafic, tephritic basalt from Svalbard (Norway) with carbonate concretions in vesicules, and hydrothermal calcareous exhalite crusts (Fig. 1), similar to those observed in the Martian meteorite ALH84001 [5]. This basalt also contains dunite xenoliths that can be considered as cumulates (*sensu lato*). ***(2)*** A primitive basalt from Etna (Italy). ***(3)*** An altered, silicified ultramafic basalt from Barberton (South-Africa). ***(4)*** An altered, silicified komatiitic basalt from Barberton (South-Africa).

Sediments: (5) 3.5-3.3 Ga-old volcanic sands (hydrothermally-silicified) from the Pilbara, Australia, and from Barberton, South Africa, that contain carbonaceous traces of microorganisms. ***(6)*** A banded iron formation (BIF) from the Pilbara, Australia. ***(7)*** A laboratory-produced nontronite. Nontronite is a typical alteration product of volcanic rocks. ***(8)*** Hydrothermal carbonate (exhalite on the Svalbard basalt).

Methods : Textural and compositional information was obtained using standard laboratory instruments. Structural and textural information was provided by visual field and hand specimen observation, as well as optical and electron microscopy study of thin sections and etched rock surfaces. Mineralogical analyses (spot and mapping) were made on rock surfaces, thin sections and powdered sample, depending on instrument type. The instruments incluede a WITec Alpha 500RA scanning confocal Raman spectrometer operating at a wavelength of 535.3 nm; and Nicollet IR spectrometer operating at a wavelength of 4000–400 cm^{-1} in transmission (the powder was melted in a KBr paste); a laboratory version of the Mimos II Mössbauer spectrometer (with a gamma radiation emitted by a ^{57}Fe source; [6]); an INEL XRM3000/CPS120 X-Ray Diffractometer with the lamba K alpha emitted by a cobalt generator, and a Cathodoluminescence detector (using a cold cathode source electron gun provide by OPEA; [7]); elemental analyses were provided by ICP-OES of powder

Results. All data are collected in an online database of Mars-anaologue materials that will accompany the Orléans-OSUC lithothèque.

As an example, we show here part of the dataset relating to carbonate globules and exhalite crusts in the ultramafic basalt from Svarlbard. The carbonate globules were compared by Treiman et al. 2002 in the Martian meteorite ALH 84001 (Fig. 1; [5]). Raman mapping shows that the zoned carbonate globules consist of siderite, magnesite, and ankerite (Fig. 1c) (cf. Steele et al 2007 [8]). Optical, cathodoluminescence (CL), Raman, IR (Fig. 2), and microprobe analysis of the finely laminated exhalite crusts show three phases: (1) an external phase of magnesite and dolomite, without Fe and Mn, that does not luminescence in CL (fig. 1e). (2) A middle layer of scalloped-textured carbonate luminescing in red in CL. (3) An internal layer luminescing in orange and red that contains Mn. The contact between the carbonates and the basalt is outlined by the presence of small grains of iron sulfides, e.g. pyrite.

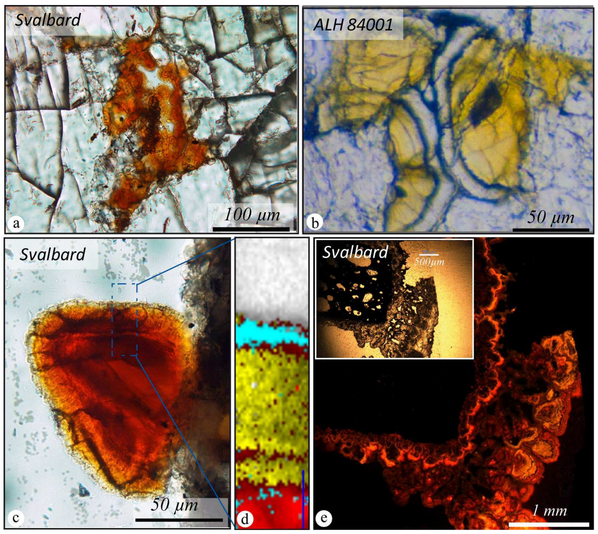

Figure 1: optical view of carbonates (a) in dunite from the Svalbard basalt compared to carbonates (b) in ALH84001 [5]; carbonates in a basaltic vesicle (c) in the Svalbard basalt with associated Raman map (d), siderite in red, dolomite in yellow and ankerite in light blue (Raman setting : obj.:x100, 1mW) . Cathodoluminescence view (e) in a carbonate exhalite crust on the outside of the basalt from Svalbard.

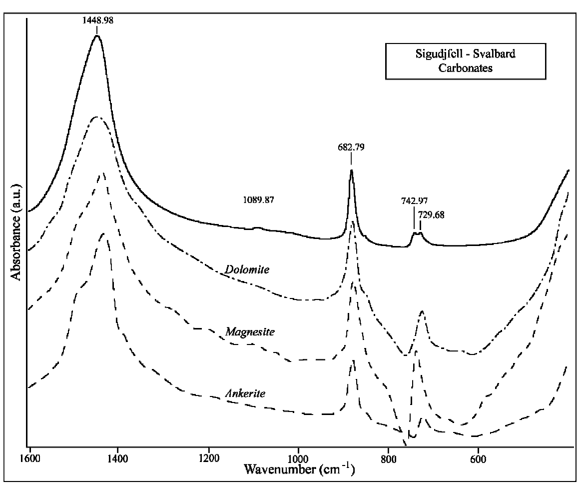

Figure 2. - IR spectra of carbonate layers and associated minerals in dotted line.

Discussion and conclusions: The preliminary suite of rocks and minerals proposed here are relevant Mars-analogues in terms of composition, texture, and origin. Martian volcanic rocks, however, are richer in Fe and Mg than terrestrial volcanics (although the komatiites have ~18% Mg). Despite this, the compositions of our terrestrial analogues plot in the same field in the total alkalis-silica diagram as the *in situ* compositions of martian volcanics, as measured by the MERs (Fig. 3).

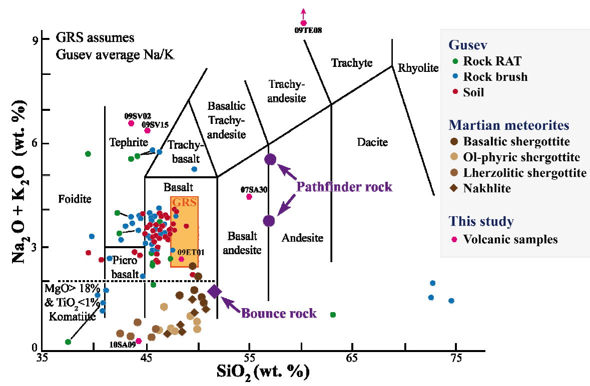

Figure 3- Total alkali-silica diagram showing the compositions of martian volcanic roks and the analogue volcanic rocks in the Orléans rock collection.(after McSween et al., 2009 [3] and Le Bas et al., 1992 [9]).

The Orléans (OSUC) Mars-analogue rock collection is an ongoing project for which we presently have an initial selection of laboratory-characterised rocks and minerals that are being used for testing the ExoMars instrument suite and will be available for the Max-C instruments during their development. The available dataset will be completed by organics analysis of the samples, and further rocks and minerals including evaporates and hydrothermal deposits. The online database containing all optical, textural and compositional information will be available to mission scientists and instrument builders. This database will be an invaluable tool during mission operations.

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References: [1] Westall F., Bost N., Ramboz C. et al. (2011) *LPSC 42*, this conference. [2] Carr M., and Head J. (2010) *Earth Planet. Sci. Lett*, *294*, 185-203. [3] McSween H. Y. et al.(2009) *Science*, *324*, 736-739. [4] Bost N., Westall F., Ramboz C. et al.(2011) *JGR*, in prep.[5] Treiman A.H. et al. (2002) *EPSL*, *204*, 323-332. [6] Klingelhöfer G. et al. (2003) *JGR*, *108*(E12), 8067. [7] Thomas R. et al. (2009). Cathodoluminescence and its Application in the Planetary Sciences, *111-126*. [8] Steele A. et al. (2007) *Meteoritics & Planetary Science*, *42*, 1549-1566. [9] Le Bas M. et al. (1992). *Mineralogy and Petrology*, *46*, 1-22.